REVUE SCIENTIFIQUE ET TECHNIQUE
DOI: 10.20506/rst.36.3.3494


# INVESTIGATION OF WAYS TO INCREASE THE RELIABILITY AND LONGEVITY OF CARCASS ELEMENTS OF INDUSTRIAL BUILDINGS AND STRUCTURES

JAMALOV J.[1]

[1]Azerbaijan Scientific-Research Institute of Construction and Architecture
Candidate of Technical Sciences, associate professor Jamalov Jasarat Aladdin
*Corresponding email: jasarat_jamalov@gmail.com

**Abstract**

The insertion of the pre-reinforced element allows to overcome the initial stresses in the reinforced structure, reinforced under the operational load. In our time, a rich practice was gathered in the area of preliminary intensification of bending and tightening of elements. Along with this, there are only a few studies on the preliminary intensification of such tightened elements. Preliminary intensification of molded building elements can be carried out in various ways (with the help of pre-strengthened tugs, telescopic pipes, intelligent communications, etc.). The reinforcement of the rods pressed in metal structures with the help of pre-strengthened tugboats allows to reduce the volume of construction and installation works to a minimum.

Key words: initial tensions, reinforcing, reinforced, construction, stability, pre-intensified, diaphragm, moment, resistance, elastic supports, collar, matrix, power crisis, protection coefficient.

**Introduction**

The investigations showed that the area of the cross-section calculated taking into consideration combined work of the reinforcing and reinforced elements is significantly less than the one calculated taking into account separate works of the above mentioned elements.

In the reinforced elements, initial tensions are to be taken into the consideration in calculations. Reinforcement process in the constructions under the loads should comply with Construction Norms and Rules of on the basis of $N_1 \leq 0,6N_0$ condition. Here, $N_1$ - is a force in the previous element in the moment of reinforcement; $N_0$ - is an account force in the pivot before reinforcement. It is due to the fact that while $N_1 > 0,6N_0$ heating of the pivot (at the result of welding) leads to increase of bending and loss of stability in the pivot. In order to increase efficiency of the reinforcement under the load, pre-intensification of the reinforcing elements are realized. Pre-intensification of the reinforcing elements allows to increase elastic work limit of it. [7,8].

Reinforcement of load-bearing constructions and the ways of regulation of tension in them. Pre-intensification of the reinforcing elements can be realized by means of electrothermal and electromechanical methods. Besides it, hydraulic jacks and other force using methods can be applied for pre-intensification. The reinforcing element is pressed (intensified) in advance with the help of any method, and then it is connected with the reinforced construction reliably in the ends. The reinforcing element released from the tows will begin to be tightened and so, will reduce the tension of the reinforced construction (tightened pivot, pillar) to some extent. The reinforced pivot is transversely connected with the tow by means of diaphragms and it provides their joint effective work.

The gap between the diaphragm and the tow (very often met in practice) affects the stability of the pivot. Account scheme of such a tow can be considered the pivot with elastic intermediate support. In the middle pass of a one-diaphragm element, in intensification process a curve emerging at the moment of lock of the gap between the diaphragm and the pivot can be determined in the following way [2].

$$f_1 = f_0 + \delta_1 = \frac{\ell}{750}\left(\frac{N_e}{N_e - N_1}\right) \tag{1}$$

Here, $f_0$ - is an initial curve; $\delta_1$ - is a gap between the tow and the diaphragm.

On another hand, if we suppose $f_1 = \frac{f_0 N_e}{(N_e - N_1^0)}$ from [2], we can determine that:

$$f_1 = f_0 + \delta_1 = \frac{f_0 N_e}{(N_e - N_1^0)} \tag{2}$$

Here, $N_1^0 = \frac{N_e \delta_1}{f_o + \delta_1}$ (3)

$N_1^0$ - is a longitudinal force emerging at the moment of the lock of the gap between the diaphragm and the tow.

If to approximate the tilted axes of the pivot with sinusoid $y = f \sin(\frac{\pi x}{\ell})$, we can write the following for the locking moment of the gap (between the diaphragm and the tow):

$$E\dot{I}y'' = -N_1 f_1 \sin\frac{\pi x}{\ell}$$

Here, we can write the following, if we take into account the values of $N_1^0 = N_1$ from (3):

$$E\dot{I}y'' = -N_1 f \sin\frac{\pi x}{\ell} = -N_e \frac{\delta_1}{f_1} f_1 \sin\frac{\pi x}{\ell} = -N_e f_1 \sin\frac{\pi x}{\ell} \tag{4}$$

Increase of the intensified pivot will stop after its distortion; the reason for it is an elastic reaction of the tow.

Elastic reaction of the tow can be determined from the equilibrium condition both in elastic and plastic stages. Under the impact of the $R_d$ force, the tow will distort from its rectilinear position and a curve will emerge in the middle pass ($f_2$). Such a curve emerges at the result of increase of $N_1$ force up to $N$ force. According to the equality condition at the place of dislocation of the middle cuts of the tow and the pivot, the curve of the tow will be equal to $f_2$ (Figure 1).

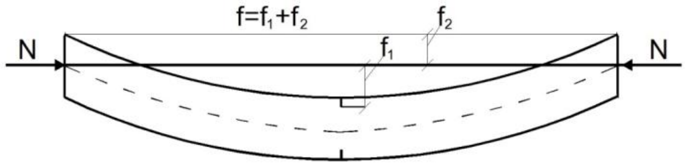


Fig. 1. Account scheme of the pivot pre-intensified by means of the longitudinal tow

From AOO1 triangle (Figure 2) we can write $f_2 = \sqrt{AO^2 - AO_1^2}$ .
$AO = 0{,}5\ell_d + \Delta\ell_d$ ; $AO_1 = 0{,}5\ell_d$

So, we get:

$$f_2 = 0{,}5\sqrt{(\ell_d + \frac{N_2\ell_d}{F_d A_d})^2 - \ell_d^2} = 0{,}5\ell_d\sqrt{\frac{N_2^2}{(E_d A_d)^2} + 2\frac{N_2}{E_d A_d}}$$

(5)

If we take into consideration approximation (at the result of shortening and bending of the pivot) of the ends of the intensified elements [3,4].

$$f_2 = 0{,}5(\ell_d - \delta_m - \Delta_m)\sqrt{\frac{N_2^2}{(E_d^2 A_d^2)} + 2\frac{N_2}{E_d A_d}} \qquad (6)$$

Here, $\delta_m$ - is the value identifying the shortening of the pivot.

The tow force will increase as much as $N_2$ at the result of the impact of $R_d$ reaction emerging in the tow in the middle pass.

As $N_2$ force and $f_2$ curve are unknown, equation (6) should be solved together with another dependence $f_2(N_2)$. Also, elastic resistance of the tow is unknown $R_d = Q_d$ .

Dependence for the added $N_2$ force after $\delta_1$ gap is closed can be written from equilibrium condition of internal and external forces (Figure 1). As the $\beta$ angle is small ($\cos\beta \approx 1$), this equilibrium condition can be written as follows after some transformations:

$$N_1 f_1 \cos\alpha - RW + \frac{N_1}{A}W = \frac{-N_2}{A}W - N_2 f_1 \cos\alpha$$

Here we get:

$$N_2 = -\frac{N_1(f_1\cos\alpha + \rho) - RW}{f_1\cos\alpha + \rho} \qquad (7)$$

Here, $R,\ W$ - are account resistance of the metal and resistance moment of the cross-section cut of the intensified element.

$$cos\alpha = \frac{E_d A_d}{N_2 + A_d E_d}$$
(8)

If we write this formula in the formula (7), we will get:

$$N_2 \le \frac{N_1(f_1+\rho)-RW}{f_1 E_d A_d/(N_2+E_d A_d)+\rho} = \frac{[N_1(f_1+\rho)-RW](N_2+E_d A_d)}{f_1 E_d A_d + \rho(N_2+E_d A_d)}$$
(9)

When the sum of $A_d$, $A_0$ and $W$ is known, it is possible to identify the value of $N_2$. If we take into consideration the value of $N_2$ in (5) and (6) formulas, we can calculate $f_2$.

It is possible to determine $Q_d$ force, supposing $R_d = Q_d$ in the middle pass of the tow as a tightened agile thread from the condition of equality of the moments to zero in regard to 0 point (Figure 2).

$$Q_d \cdot \frac{\ell}{2} - N_2 \cos\alpha \cdot f_2 = 0$$

$$Q_d = \frac{1}{\ell} 4 N_2 f_2 \cos\alpha = \frac{4 N_2 f_2}{\ell(1+N_2/E_d A_d)}$$

Here,
(10)

$\ell -$ is the distance between the connected ends of the tow.

It is also possible to determine this value of $Q_d$ from the equilibrium condition of the intensified element in elastic stage.

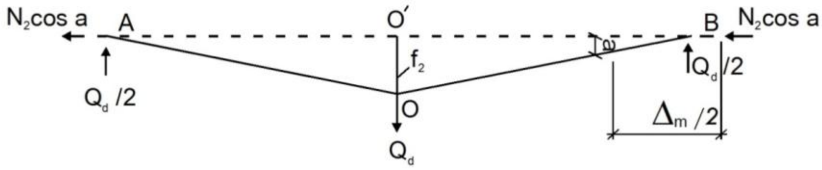


Fig. 2. Scheme of the reinforcement by means of a tow of a reinforcing element having just one diaphragm in the middle pass (account scheme of the tow).

The moment of the external forces in regard to the point located in the middle pass, is regulated with the moment of the internal forces.

$$\sum M_0 = 0{,}5 Q_d \cdot \frac{\ell}{2} - N_1 f_1 + N_2(f_1 + f_2)\cos\alpha = [R - (N/A_0)]W_0$$

From here we get:

$$Q_d = \frac{4}{\ell}[N_1 f_1 - N_2(f_1+f_2)\cos\alpha + (R - N/A_0)W_0] =$$

$$= \frac{4}{\ell}\left[N_1 f_1 - N_2(f_1+f_2)\frac{E_d A_d}{N_2 + A_d E_d} + RW - \frac{N}{A_0}W_0\right]$$
(11)

Here, $N = N_1 + N_2$; $R$ - is an account resistance of steel;

$$\sum M_0 = N_1 f_1 + N_2(f_1 + f_2)\cos\alpha - \frac{Q_d \ell}{4} = -(R - \frac{N}{A_0})W_0$$

From here we can write:

$$Q_d = \frac{4}{\ell}\left[N_1 f_1 + N_2(f_1 + f_2)\cos\alpha + (R - \frac{N}{A_0})W_0\right] =$$

$$= \frac{4}{\ell}\left[N_1 f_1 + N_2(f_1 + f_2)\frac{E_d A_d}{N_2 + A_d E_d} + (R - \frac{N}{A})W_0\right] \quad (12)$$

under the impact of $N_1$, $N_2$, $Q_d$, the general curve $f = f_1 + f_2$ will be as differential equation of the bent axis of the obtained intensifying element:

$$E\dot{I}\frac{d^2 y}{dx^2} = -\left[N_1 f_1 \cos\alpha + N_2(f_1 + f_2)\cos\alpha - \frac{Q_d \ell}{4}\cos\alpha\right]$$

In this equation, if to write the values of $y = f\sin(\frac{\pi x}{\ell})$ and $Q_d$ (9), we will get:

$$E\dot{I}\frac{d^2}{dx^2} f(\sin\frac{\pi x}{\ell}) = -(N_1 + N_2) f_1 \cos\alpha$$

If to conduct differentiation, we will get:

$$E\dot{I}\frac{\pi^2}{\ell^2} f = \cos\alpha(N_1 + N_2) f_1 \quad (13)$$

If to consider $N_e = E\dot{I}\frac{\pi^2}{\ell^2}$, we can write:

$$N_e f = (N_1 + N_2)\cos\alpha \cdot f_1 = N_1 f_1 \cos\alpha + N_2 f_1 \cos\alpha$$

We get the following after some transforms of the equation (13):

$$N_2 = N_e \frac{(f_1 + f_2 - \delta_1)}{f_1\left[1 - \frac{N_e}{E_d A_d}(\frac{f_1 + f_2}{f_1})\right]} = N_e(f - \delta_1)\frac{E_d A_d}{f_1 E_d A_d - N_e f}$$

(14)

If to solve this equation according to $f_2$ and to write the value of $N_2$ (7) in its place and to conduct some transforms, and to suppose the small value of $\alpha$ as $\cos\alpha \approx 1$, we will get the following:

$$f_2 = \frac{[N_1(f_1 + \rho) - RW]\cdot f_1(1 - N_e / E_d A_d) + N_e f_0(f_1 + \rho)}{[N_1(f_1 + \rho) - RW](1 + N_e / E_d A_d)}$$

(15)

When $N_2$ force is $\cos\alpha = 1$, it will be equal to zero and it means that the gap between the curved diaphragm determined by the formula (14) and the tow will be a curve formed before it closes.

When $N_2$ and $f_2$ are known, it is possible to calculate $Q_d$ with the help of the formula (10).

It is possible to check hardness and stability of the intensified element using the values of $N_1$, $N_2$, $f_1$, $f_2$, $Q_d$. According to the account scheme of the intensified element (Figure 3), taking into consideration the formula (10), and supposing that the force $Q_d$ balances with $N_2$, we will get (a balance equation is written in regard to the middle pass (zero point)):

$$\sigma \le R_y \tag{16}$$

$$\sigma = (N_1 + N_2)\cos\beta \frac{1}{A} + M_N \frac{1}{W} - Q_d \frac{\ell}{4} \cdot \frac{1}{W}$$

Here,

$$M_N = [N_1 f_1 + N_2 (f_1 + f_2)]\cos\alpha$$

From the formula $(\frac{\ell}{2})^2 - f_1^{\,2} = (\frac{\ell}{2})^2 \cos^2\beta$ we get (Figure 5.3):

$$\cos\beta = \sqrt{1 - \frac{4f_1^2}{\ell^2}}$$

Taking into consideration the values of $\sigma$, $M_N$, $\cos\alpha$, $\cos\beta$ and $Q_d$, the condition (12) can be written as follows:

$$\sigma = \frac{N_1 + N_2}{A}\left[\sqrt{1 - \frac{4f_1^2}{\ell^2}} + \frac{Af_1}{W} \cdot \frac{1}{1 + N_2 / E_d A_d}\right] \le R_y \tag{17}$$

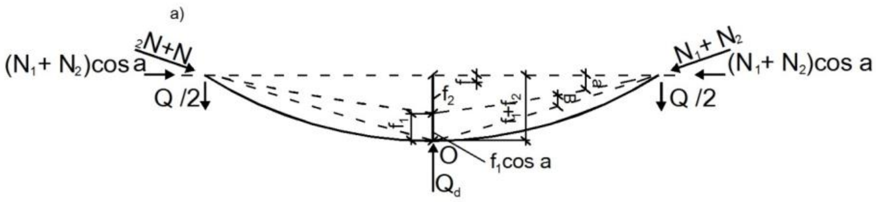


Fig. 3. Account scheme on verification of stability of the intensified element

If to take into consideration that even when $f_1 / \ell = 1/200$, it is $\cos\beta \approx 1$ and

$$\frac{A}{W} = \frac{Ay}{I} = (\frac{1}{r_1})^2 y = \frac{y}{r_1^2}; \qquad N = N_1 + N_2$$

The formula (17) can be written as follows:

$$\frac{N}{A}(1 + \frac{f_1 y}{r_1^2} \cdot \frac{1}{1 + N_2 / E_d A_d}) \le R_y \tag{18}$$

Or,

$$\frac{N}{A}\eta \le R_y \tag{19}$$

$$\eta = 1 + \frac{f_1 y}{r_1^2} \cdot \frac{1}{1 + N_2 / E_d A_d}$$

Here, $y$ - is the distance from the center of gravity of the cut until the most intensified fiber; $r_1$ - is a radius of an inertia cut.

As it seems from the formulas (3), (18) and (19), the load capacity of an element with one diaphragm in the middle pass intensified by the help of the tow will be as much more as $n$ than the similar element without diaphragm (cross section) where,

$$n = \frac{\delta_1}{f_0 + \delta_1} + \frac{f_0 + f_2}{\frac{N_e}{E_d A_d} f_2 + (f_0 + \delta_1)(1 - \frac{N_e}{E_d A_d})} \qquad (20)$$

Availability of a gap between the diaphragm and the tow leads to reduction of $n$ parameter.

The reinforced element connected with the clamps and other fastening means with the reinforced pivot can be considered as a pivot on elastic supports. In this case, the reinforcing element undergoes a pressing by a pre-intensifying force $N_q$, and elastic supports serve as one-sided communication.

Collapse rate of such a one-sided communication (elastic supports) will depend both on bending hardness of the reinforcing (main) element and location of these supports alongside the pass. The number of intermediate supports should be taken so that besides ensuring stability of the reinforcing element, also the necessary level of pre-intensifying force was achieved.

In other words, the number of the intermediate supports (clamps) should be taken so that the bending stiffness of the reinforcing element was minimum [2,3].

For the above stated case:

$$N_q < P_{kr} \qquad (21)$$

That is, pre-intensifying force $N_q$ should not be less than the crisis load $P_{kr}$ of the intensified element.

In order to solve this issue, account scheme of the most unsuitable work of the reinforced and reinforcing elements should be considered. Fastening clamps (elastic supports) should be installed in such a way that they did not limit the movement of the reinforcing pivot in longitudinal direction. Exacerbation of the reinforcing element in advance can be accepted as a pivot with elastic intermediate supports and exposed to longitudinal pressing force (Figure 4).

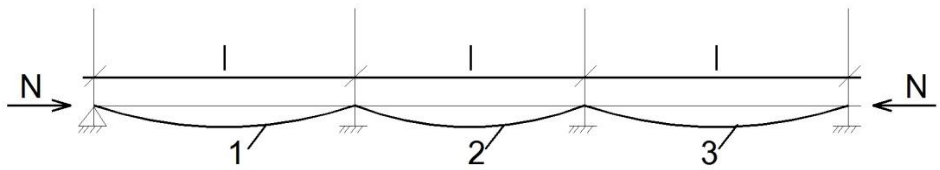


Fig. 4. High tide scheme of reinforcing element.

At the result of the preliminary intensification (longitudinal pressing) loss of stability depending on the number of the high tide waves ($k$) of the reinforcing pivot can take place in the different values of the crisis load.

When hardness of intermediate supports is small, the reinforcing pivot will swell only over one wave. When hardness is increased, high tides of the reinforcing pivot will increase and the value of the crisis load will increase.

In this case, the number of the high tide waves will be equal to the crisis value and increase of hardness of the supports will not lead to increase of their number. It can occur in the case when there is enough space between the reinforcing and reinforced elements, otherwise, additional high tide waves will emerge in the places where clumps have been put. If collapse of the supports is very little, then their protection coefficient "$k_0$" will be determined as follows:

$$k_0 = \alpha \frac{\pi^2 EI}{\ell^2} \quad (22)$$

Here, $\ell$ - the distance between the intermediate supports is given in the work [11] of the value of $\alpha$ - coefficient, it depends on the number of the passes and is called characteristic numbers of protection coefficients.

Ensuring stability of protection coefficient (i.e. ensuring stability of the value of "$k_0$" coefficient) bears important practical significance as the given value of this coefficient being more or less than that one calculated by means of the formula (22) indicates availability of zero points on elastic supports during the high tide.

Let's have a look at an elastic system loaded with external load groups given via certain $\gamma$ parameter. Let's make small replacements in the system $\delta_i (i = 1, \ 2, ..., n)$. In this case, besides $\delta$ replacements, additional external forces (support reactions) will emerge in the considered system:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix} \quad (23)$$

Given group of external forces creates moments according to $i$ - points:

$$M\gamma = \gamma A \delta \quad (24)$$

Here $A$ - is a numerical matrix depending on the type of the device and loading regulations.

On another hand, external reaction is a bending moment formed from $R$ forces on $i$ - points:

$$M_R = L_m R \quad (25)$$

Here, $L_m$ - is a matrix compiled from the ordinates of the penetration lines of the moments.

$R$ - reaction forces depend on $\delta$ - values.

$$R = B\delta \quad (26)$$

Here, $B$ - is a non-specific matrix.

So it can be written [9]:

$$M_R = L_m B \delta \quad (27)$$

Total bending moment on considered $i$ -points:

$$M = A\delta + L_m B \delta \quad (28)$$

Let's replace elastic load $q = M / E\dot{I}$ with elastic $W_i$ loads $(i = 1, \quad 2, ..., n)$. Then let's write the equation of curves taking into consideration replacement of the bending moments with impact matrix $L_m$ in the girder cuts:

$$y = L_m W \tag{29}$$

Elastic loads for the whole systems are determined with the following formula:

$$W_n = \int \frac{M_p \vec{M}_m}{E\dot{I}} ds + k \int \frac{Q_p \vec{Q}_m}{GA} ds + \int \frac{N_p \vec{N}_m}{EA} ds \tag{30}$$

If to replace the opposite points of the moment diagram between the neighboring $n-1$, $n$ and $n+1$ cuts with a straight line and to take into the consideration only the first integral in formula (30), elastic loads can be calculated with this formula:

$$W = \frac{S}{6E\dot{I}} D\vec{M} \tag{31}$$

Here, $S$ - is a distance between the cuts; $D$ - is a Jacobi matrix; $M$ -is the bending moments in the cuts [10].

$$D = \begin{bmatrix} \alpha_{11} & \alpha_{12} & & & \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & & \\ & \alpha_{32} & \alpha_{33} & \alpha_{34} & \\ & \dots & \dots & \dots\alpha_n(n-1) & \alpha_{nn} \end{bmatrix} \tag{32}$$

The elements of the matrix are determined in the following way:

$$\alpha_k(k-1) = \rho_n \; ; \qquad \alpha_{kk} = 2(\rho_n + \rho_{n+1}) \; ; \qquad \alpha_k(k+1) = \rho_{n+1} \tag{33}$$

Here,

$$\rho_n = S_n \dot{I}_0 / \dot{I}_n S_0 \tag{34}$$

For the stability issue of the pre-intensified element we have considered: $\rho_n = \rho_{n+1}$ ( $S_n = S_0$ , $\dot{I}_n = \dot{I}_0$ ). In that case $\alpha_k(k-1) = 1$ ; $\alpha_{kk} = 4$ ; $\alpha_k(k+1) = 1$

So, we get:

$$\vec{W} = \frac{S}{6} D_1 (\frac{\vec{M}}{E\dot{I}}) \tag{35}$$

Here, $\frac{M}{E\dot{I}} = q_x$ - is the ordinates of the elastic loads on $i = 1, \quad 2, ..., n$ points.

$$D_1 = \begin{bmatrix} 4 & 1 & & & \\ 1 & 4 & 1 & & \\ & 1 & 4 & 1 & \\ \dots & \dots & \dots & \dots\dots 1 & 4 \end{bmatrix} \tag{36}$$

Here, $D_1$ -is a modular Jacobi matrix.

In this case, we will get the following for determining the replacements:

$$\vec{y} = \frac{S}{E\dot{I}} D(\vec{M}) \qquad (37)$$

If a high-precision is requested in determination of replacements, then in this case, it is possible to replace the diagram of the bending moments between two neighboring points ($n-1$, $n$, $n+1$) with a square parabola passing through three points (Figure 5).

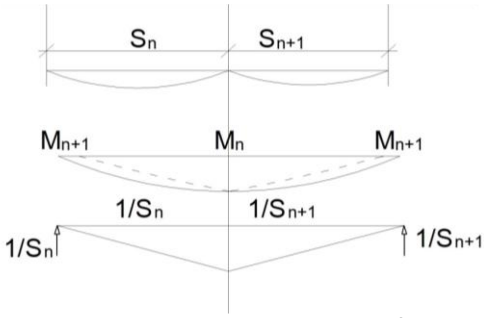


Fig. 5. A scheme on calculation of a pressed pivot with intermediate elastic supports by the method of elastic loads.

.

In this case, more precise value of $\vec{y}$ - will be identified in such a way:

$$\vec{y} = \frac{S}{6E\dot{I}} D(\vec{M}) \qquad (38)$$

If we will take into consideration that $D = D(4{,}1) = 5D^{(1,\ 0{,}1)}(\vec{M})$ is in equal unit (linear) hardness, then, it can be written [9].

$$\vec{y} = \frac{5S}{6E\dot{I}} D^{(1,\ 0{,}1)}(\vec{M}) \qquad (39)$$

Here,

$$D^{(1,\ 0{,}1)} = \begin{bmatrix} 1 & 0{,}1 & & & \\ 0{,}1 & 1 & 0{,}1 & & \\ & 0{,}1 & 1 & 0{,}1 & \\ \dots & \dots & \dots & \dots\dots 0{,}1 & 1 \end{bmatrix} \qquad (40)$$

If to write the value of (28) in its place in the formula (35) :

$$\vec{W} = \frac{S}{6E\dot{I}} (\gamma D_1 A\delta + D_1 L_m B\delta) \qquad (41)$$

Using $L_m$ from the impact matrixes of the moments, we can write:

$$\delta = L_m W = L_m \frac{S}{6E\dot{I}} (\gamma D_1 A\delta + D_1 L_m B\delta)$$

(42)

We can write the formula (42) in such a form if to include $K = L_m DA$, $C = L_m DB$, $\alpha = S/6E\dot{I}$ markings:

$$\delta = \alpha\gamma K\delta + \alpha C\delta$$

Or $\gamma K\delta = \left[\frac{1}{\alpha}E - B\right]\delta$,

(43)

If to conduct a number of transforms here, we will get:

$$(K_0 - \frac{1}{\gamma}E)\varepsilon = 0 \qquad (44)$$

Here, $K_0 = K\left[(1/\alpha)E - B\right]^{-1}$.

The analysis of the formula (44) shows that the crisis case of the system will emerge when it is $\delta \neq 0$.

In that case,

$$\left|K_0 - \frac{1}{\gamma}E\right| = 0 \qquad (45)$$

This equation becomes possible only if we accept the values of characteristic numbers of $K_0$ ($\lambda_1$ > $\lambda_2$ >...> $\lambda_n$), for $1/\gamma$ sum, the crisis for these characteristic numbers will correspond to $1/\gamma_1$; $1/\gamma_2$; . . .; $1/\gamma_n$ parameters. Finally, solution of the issue leads to determination of the minimum value of the crisis load [6].

As it seems from the $\gamma_i = 1/R_i$ equality, the parameter of $\gamma_{kr}$ corresponds to the value of $\lambda_{\max}$. So, for solution of stability the greatest characteristic number of $K_0$ matrix should be found.

We can write the formula (45) in the following form after a number of transforms:

$$\left|K - \lambda E\right| = 0 \qquad (46)$$

Here, $\lambda = 1/\alpha\gamma$,

From the formula (46) we get:

$$\gamma_{kr} = \frac{6E\dot{I}}{S\lambda_{\max}} \qquad (47)$$

In the formula (46), $K$ matrix is determined as the sum of three matrixes:

$$K = L_m DA \qquad (48)$$

The reinforcing element works as a pivot resting on an elastic basis and exposed to pressing. Here reinforced element serves as the elastic basis. In this case, the loads are passed to the reinforced elements by means of clumps and high tide semi-waves of the reinforcing element (Figure 6).

**Fig. 6. Account scheme of the reinforcing element.**

If to take into consideration that there is a certain gap (at the result of hard fastening of clumps) between the reinforcing and reinforced elements and the impact of the clumps is like one-sided communication, high tide of the reinforcing element will have semi-waves in minimum quantity. We suppose the collapse of the intermediate supports located in equal distances in the middle of the intensified element equal to each other. And we accept elasticity coefficient (hardness degree) of a separate support equal to the reaction force creating a single replacement in perpendicular direction of an axis of the pivot of that support. General hardness of all intermediate supports is accepted approximately as follows: [1,4,5].

$$_{\sum}\alpha = K_1 \alpha_1 n$$

Here, $\alpha_1$ - is the hardness of the most collapsed support; $n$ - is the number of the supports; $K_1$ - a coefficient accepted depending on the type of the support (jointed or stiff). Impact of elastic supports located in equal distances can be replaced by an equivalent impact of elastic environment.

Hardness coefficient of such an environment can be expressed in the following way:

$$\gamma = \sum \alpha / \ell_n \qquad (49)$$

Here, $\ell_n$ - is the distance between the intermediate supports (clumps).

In this case, the crisis load of the intensified element will be determined by means of the following formula [1,5].

$$P_{kr} = \frac{\pi^2 E\dot{I}}{\ell^2}(K_1^2 + \frac{\gamma \ell^4}{K_1^2 \pi^4 E\dot{I}}) \qquad (50)$$

Here, $K_1$ - is the number of semi-waves formed at the moment of high tide in the intensified (intensifying) element; $E\dot{I}$ and $\ell$ - are consequently hardness and length of the element. Supposing hardness of the elastic environment as $\gamma$ minimum, we determine such a value of the crisis load that in this value, loss of stability of the pivot takes place in two neighboring forms, i.e. loss of stability emerges when the number of semi-waves are equal to $K_1$ and $K_1 - 1$.

If to suppose the minimum value of the crisis load as much as the number of the semi-waves as $K_1 - 1$ in the formula (50), we will get:

$$P_{kr}^{K-1} = \frac{\pi^2 E\dot{I}}{\ell^2}\left[(K_1 - 1)^2 + \frac{\gamma \ell^4}{(K_1 - 1)^2 \pi^4 E\dot{I}}\right] \qquad (51)$$

If loss of the semi-waves is equally possible both in $K_1 - 1$ and $K_1$ - numbers, then in this case, we get the above shown from the condition $P_{kr}^{K_1-1} = P_{kr}^{K_1}$ :

$$\frac{\pi^2 E\dot{I}}{\ell^2}\left[(K_1 - 1)^2 + \frac{\gamma \ell^4}{(K_1 - 1)^2 \pi^4 E\dot{I}}\right] = \frac{\pi^2 E\dot{I}}{\ell^2}(K_1^2 + \frac{\gamma \ell^4}{K^2 \pi^4 E\dot{I}})$$

Here, after some simplifications we get:

$$\frac{\gamma \ell^4}{\pi^4 E\dot{I}} = K_1^2 (K_1 - 1)^2 \qquad (52)$$

From this formula we identify $\gamma$.

$$\gamma = \frac{K_1^2 (K_1 - 1) \pi^4 E\dot{I}}{\ell^4} \qquad (53)$$

If to write this value in its place in the formula (50), we will get:

$$P_{kr} = \frac{\pi^2 E\dot{I}}{\ell^2} (2K_1^2 - 2K_1 + 1) \qquad (54)$$

Or,

$$P_{kr} = P_e (2K_1^2 - 2K_1 + 1) \qquad (55)$$

Here, $P_e$ - is a crisis force in the girder without intermediate supports.

If to write the account value of the pre-intensifying force $N_g < P_{kr}$ to the left side of the formula (55), we will get the minimal quantity of the semi-waves of the intensified element in high tide:

$$2K_1^2 - 2K_1 + 1 = \frac{N_g}{P_e} \qquad (56)$$

Start of the high tide of the intensified element as a rule, takes place at the result of availability of the big spaces between it and the reinforced element (presence of an initial bending and not good fastening of clumps). At the result, the number of the semi-waves will be minimum and bending points of the intensified element will be formed most likely in the cuts where the clumps have been put.

Outcome

Formulas have been worked out in order to calculate $N_2$, $f_2$ and $Q_d$ parameters included to the balance equations and considered as the pivot working with pressing and reinforced with pre-intensified element. A rule is given for checking hardness and stability of the intensified element using the values of $N_1$, $N_2$, $f_1$ $f_2$ and $Q_d$.

It has been noted that the load capacity of the element with one diaphragm located in the middle pass and intensified by means of a tow will be as much as "$n$" than the similar element without diaphragm ($n = (N_1 + N_2) / N_e$).

A formula has been worked out to determine the replacement at the result of the pre-intensification of the tow connected with the main element by means of the diaphragms. Besides it, canoenic equation has been compiled in order to ensure the stability, and a matrix has been formed for $K_o$ protection coefficient of the tow.

A formula has been worked out for determination of the crisis load of the intensified pivot. It was noted that loss of stability takes place over two neighboring form and allows to create a formula for calculation of the value of the crisis load depending on "$K_1$" number of semi-waves.

tability of the pivot reinforced by means of the reinforcing elements has been considered and it has been noted that the value of the crisis tension of the pivot reinforced under the load by means of pre-intensified elements is very close to the value of the crisis tension of the unloaded pivot.

## References


37. Aghayev N.H. Statistic stability issues of non-central pressed and pressed and bent pivots // Theoretical and applied mechanics, Baku: 2011, № 1-2, p. 22-24.
38. AzDTN 2.16-1 “Concrete and iron-concrete constructions”. Projecting norms”, Baku: 2015, 131 p.
39. Devyateva G.V. Technical reconstructions and modernization of buildings, [text]. Tutorial, Moscow, Infra-M, 2003, 256 p.
40. Desyatov B.I. The research of the work of the elements of welding steel forms under the tension: Abstract on competition on scientific degree on technical sciences., M.: 1969, 11 p.
41. Jamalov J.A. About calculation of reliability of construction // “System technologies” 11(66), ISSN 1562-9945. Dnepropetrovsk: 2010, p. 122-126.
42. Kikin A.I. Characteristics of projecting of steel constructions of building of metallurgical plants taking into account operation conditions: Under edition of N.S.Strelechkiy «Issues on application of steel constructions in construction». ВНИТО Dissertation of Doctor of Technical sciences. M.: 1953, 35 p.
43. Kolesnikov V.M. Investigation of the work of some steel constructions and separate elements reinforced under the load: Abstract on competition on scientific degree on technical sciences., L.: ЛИСИ, 1967, 16 p.
44. Lashenko M.N. Regulation of tensions in metal constructions. M.-L.: Stroyizdat, 1966, 190 p.
45. Smirnov A.F. Static and dynamic stability of constructions. M.: 1947, 250-290 p.
46. Smirnov A.F. Stability and fluctuations of constructions. M. Stroyizdat, 1958, 96-112 p.
47. Chuvikin G.M. Stability of frames and pivots. M. Gosstroyizdat, 1961, p. 96